US009478391B2

(12) **United States Patent**
Matsumoto

(10) **Patent No.: US 9,478,391 B2**
(45) **Date of Patent: *Oct. 25, 2016**

(54) **CHARGED PARTICLE BEAM WRITING APPARATUS AND CHARGED PARTICLE BEAM WRITING METHOD**

(71) Applicant: **NuFlare Technology, Inc.**, Yokohama (JP)

(72) Inventor: **Hironobu Matsumoto**, Kanagawa (JP)

(73) Assignee: **NuFlare Technology, Inc.**, Yokohama (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/620,402**

(22) Filed: **Feb. 12, 2015**

(65) **Prior Publication Data**

US 2015/0279611 A1 Oct. 1, 2015

(30) **Foreign Application Priority Data**

Mar. 26, 2014 (JP) 2014-064628

(51) **Int. Cl.**
H01J 37/147 (2006.01)
H01J 37/317 (2006.01)

(52) **U.S. Cl.**
CPC ***H01J 37/147*** (2013.01); ***H01J 37/3174*** (2013.01); *H01J 37/3175* (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01J 2237/31762; H01J 37/3026; H01J 37/3174; H01J 2237/1504; H01J 2237/31764; H01J 37/147; H01J 37/3175; H01J 2237/31754; H01J 2237/31776; H01J 37/02; H01J 37/153; H01J 37/20; B82Y 10/00; B82Y 40/00; Y10S 430/143
USPC ..... 250/396 R, 397, 492.1, 492.2; 700/1, 2, 700/4, 7
See application file for complete search history.

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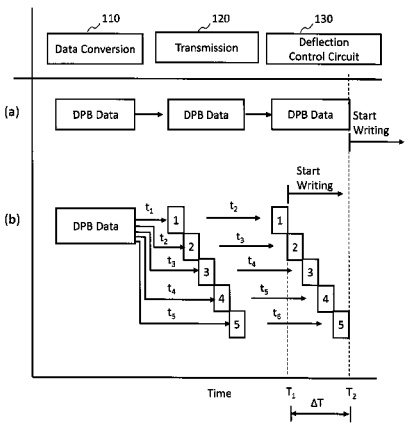
Primary Examiner — Dionne H Pendleton
(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

A charged particle beam writing apparatus includes plural conversion processing units to perform data conversion processing in parallel for writing data of each processing region obtained by virtually dividing the writing region of a target object into plural processing regions, a transmission unit to input a part of processing data of one of the plural processing regions for which data conversion processing has been performed, one part at a time, totally as n divided processing data, and sequentially transmit the n divided processing data such that the (n−1) th divided processing data is transmitted while the n-th divided processing data is being input, a deflection control circuit to control a deflection amount for deflecting a charged particle beam, based on one of the n divided processing data transmitted sequentially, and a writing unit to write a pattern by deflecting the charged particle beam based on the deflection amount.

10 Claims, 8 Drawing Sheets



(52) **U.S. Cl.**
CPC *H01J2237/1504* (2013.01); *H01J 2237/31762* (2013.01); *H01J 2237/31764* (2013.01); *H01J 2237/31776* (2013.01)

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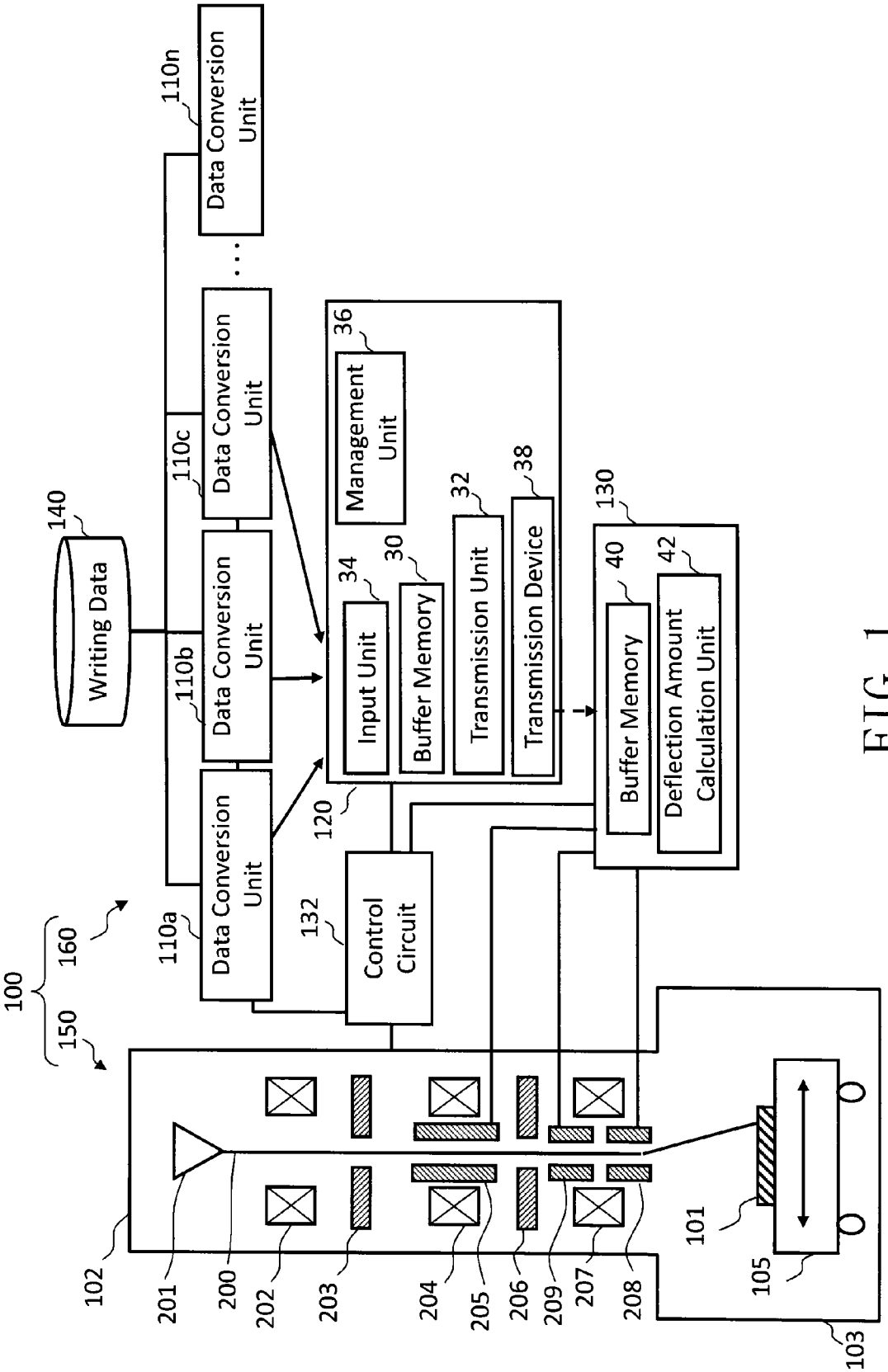
100
150
160
102
201
200
202
203
204
205
206
209
207
208
101
105
103
110a
Data Conversion Unit
110b
Data Conversion Unit
110c
Data Conversion Unit
110n
Data Conversion Unit
140
Writing Data
120
132
Control Circuit
34
Input Unit
30
Buffer Memory
32
Transmission Unit
38
Transmission Device
36
Management Unit
130
40
Buffer Memory
42
Deflection Amount Calculation Unit

FIG. 1

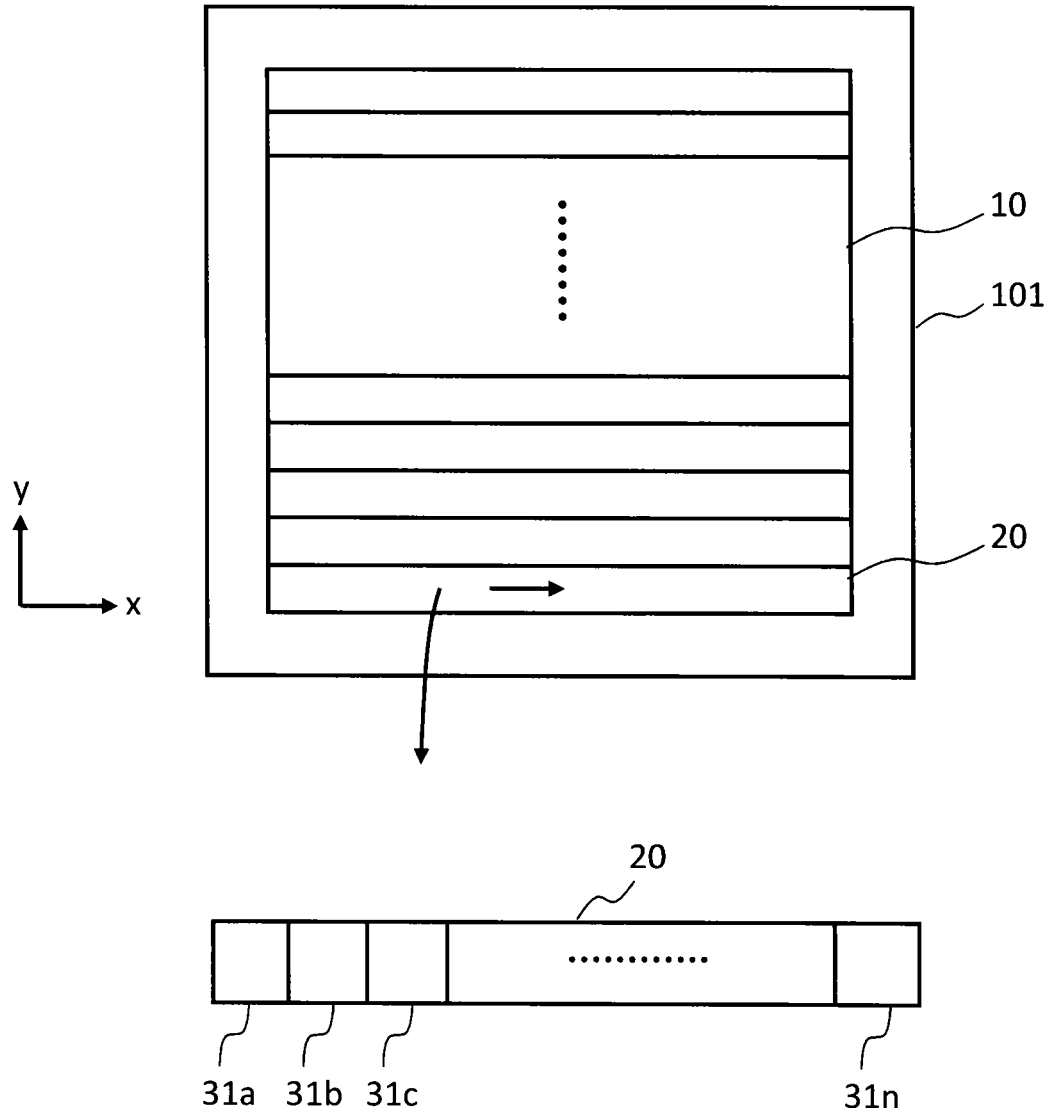

FIG. 2

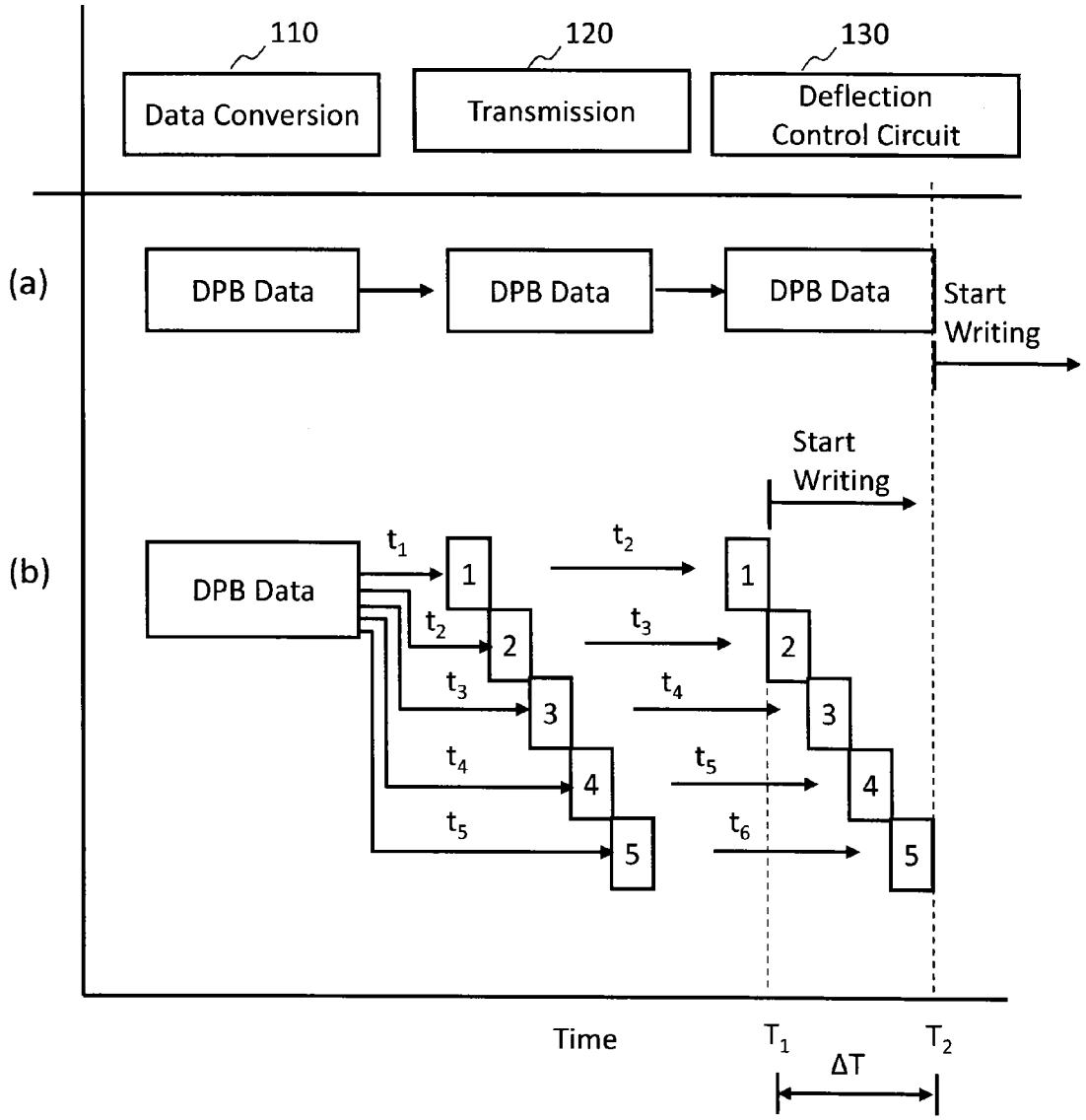
110
120
130
Data Conversion
Transmission
Deflection Control Circuit
(a)
DPB Data
DPB Data
DPB Data
Start Writing
Start Writing
(b)
DPB Data
t1
t2
t3
t4
t5
t6
1
2
3
4
5
Time
T1
T2
ΔT

FIG. 3

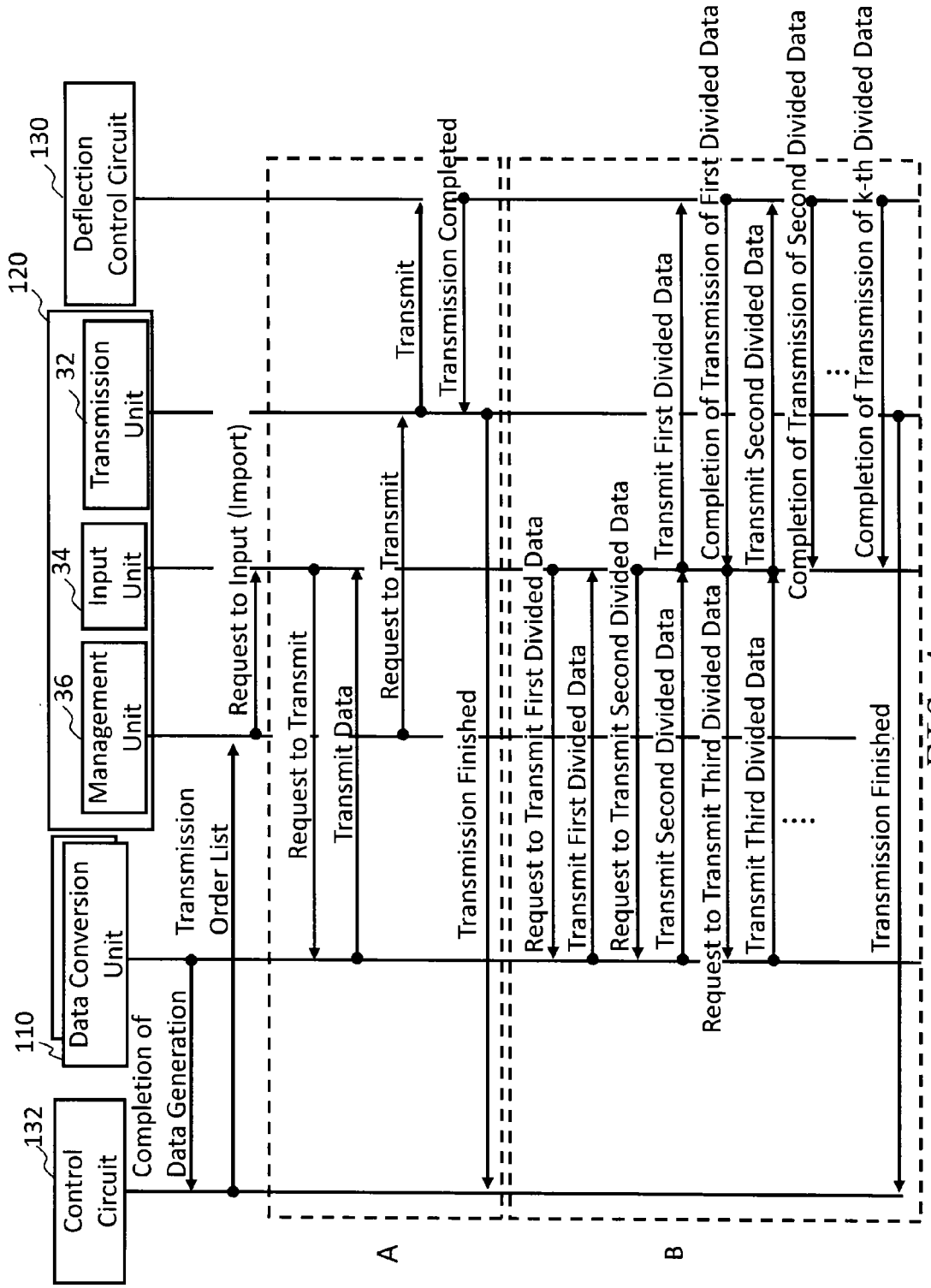
Control Circuit
132
Data Conversion Unit
110
Management Unit
36
Input Unit
34
Transmission Unit
32
120
Deflection Control Circuit
130
Completion of Data Generation
Transmission Order List
Request to Input (Import)
Request to Transmit
Transmit Data
Request to Transmit
Transmit
Transmission Completed
Transmission Finished
Request to Transmit First Divided Data
Transmit First Divided Data
Request to Transmit Second Divided Data
Transmit Second Divided Data
Transmit First Divided Data
Completion of Transmission of First Divided Data
Request to Transmit Third Divided Data
Transmit Third Divided Data
Transmit Second Divided Data
Completion of Transmission of Second Divided Data
Completion of Transmission of k-th Divided Data
Transmission Finished
A
B

FIG. 4

Transmission Order List (Import Request List)

DPB.ID.	CONV.ID.
31,1,2	A
32,1,2	B
33,1,2	C
⋮	⋮

FIG. 5

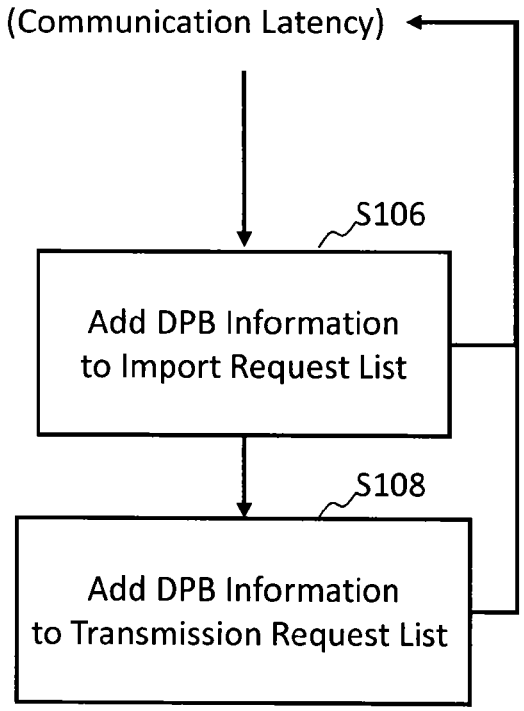

FIG. 6

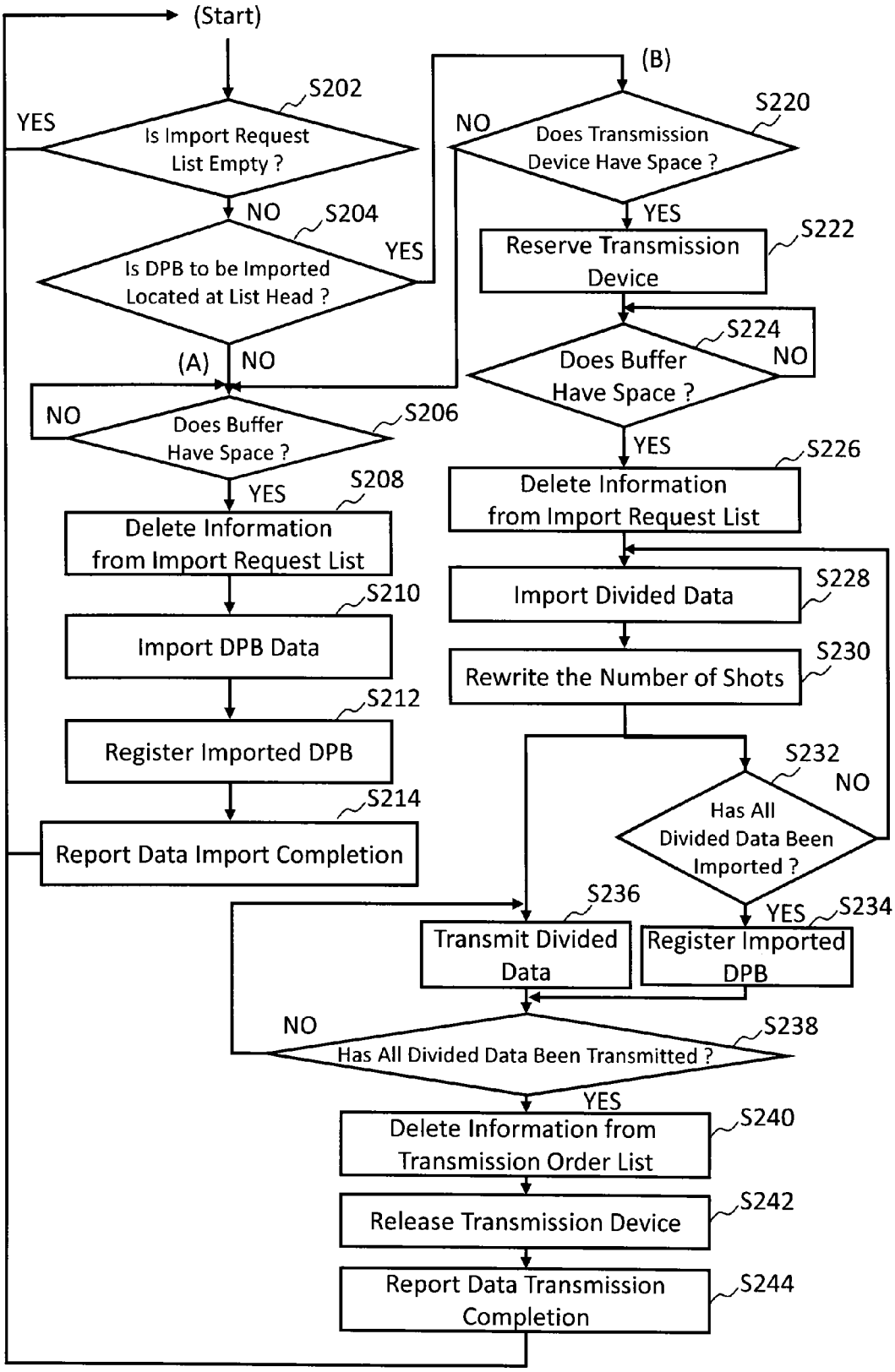
(Start)
S202
Is Import Request List Empty ?
YES
NO
S204
Is DPB to be Imported Located at List Head ?
YES
(A)
NO
NO
Does Buffer Have Space ?
S206
YES
S208
Delete Information from Import Request List
S210
Import DPB Data
S212
Register Imported DPB
S214
Report Data Import Completion
(B)
S220
Does Transmission Device Have Space ?
NO
YES
S222
Reserve Transmission Device
S224
Does Buffer Have Space ?
NO
YES
S226
Delete Information from Import Request List
S228
Import Divided Data
S230
Rewrite the Number of Shots
S232
Has All Divided Data Been Imported ?
NO
YES
S234
Register Imported DPB
S236
Transmit Divided Data
NO
S238
Has All Divided Data Been Transmitted ?
YES
S240
Delete Information from Transmission Order List
S242
Release Transmission Device
S244
Report Data Transmission Completion

FIG. 7

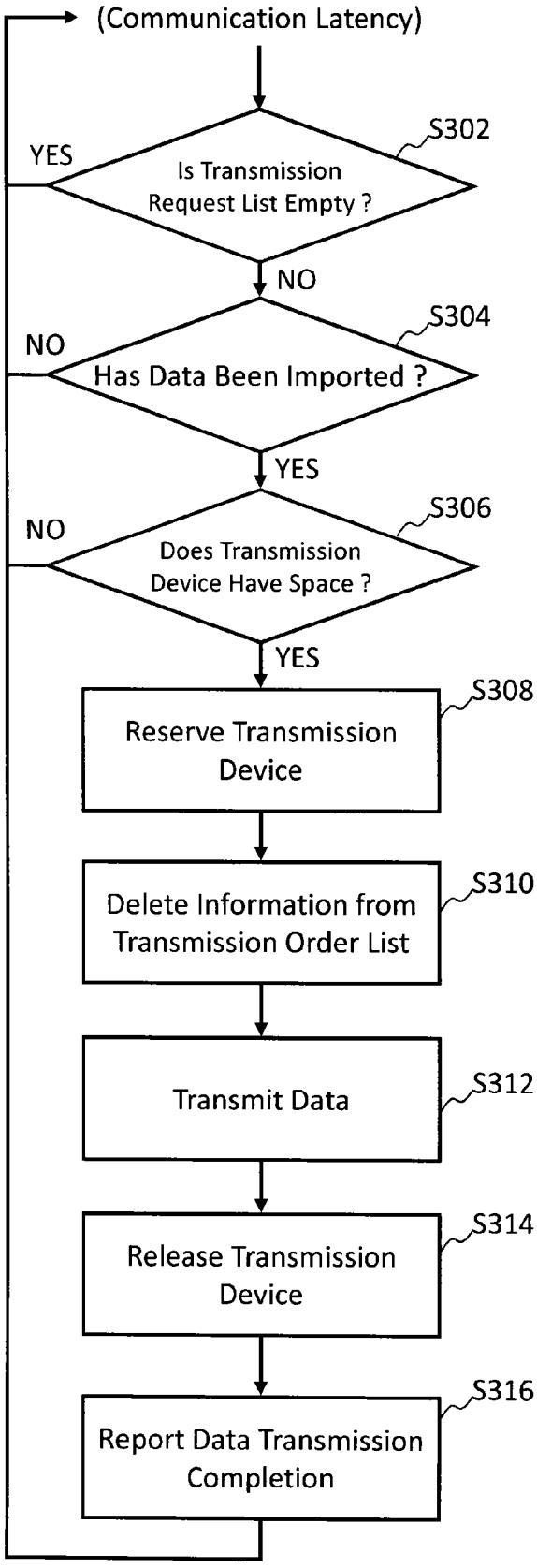
(Communication Latency)
S302
Is Transmission Request List Empty ?
YES
NO
S304
Has Data Been Imported ?
NO
YES
S306
Does Transmission Device Have Space ?
NO
YES
S308
Reserve Transmission Device
S310
Delete Information from Transmission Order List
S312
Transmit Data
S314
Release Transmission Device
S316
Report Data Transmission Completion

FIG. 8

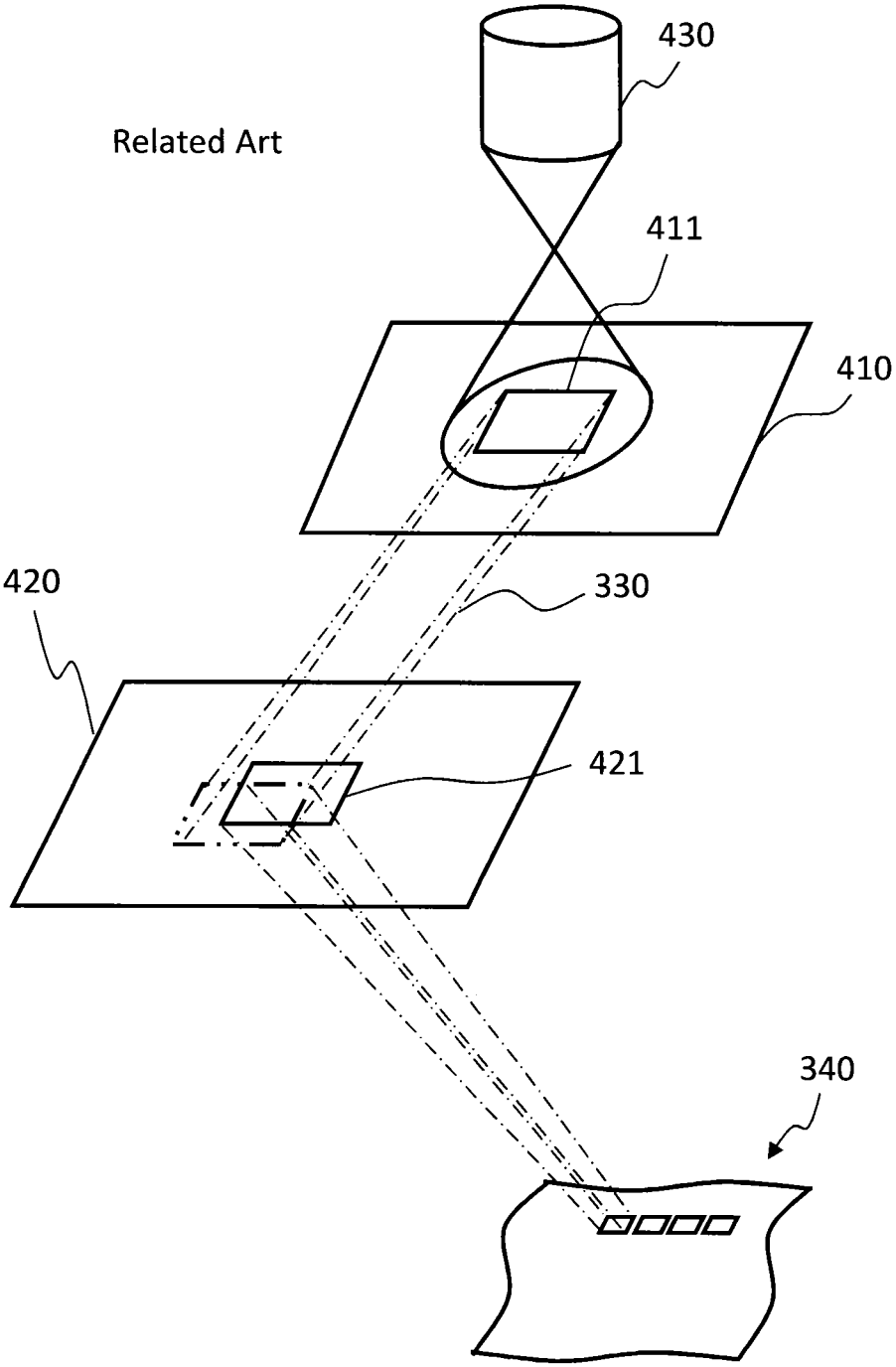

FIG. 9

CHARGED PARTICLE BEAM WRITING APPARATUS AND CHARGED PARTICLE BEAM WRITING METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2014-064628 filed on Mar. 26, 2014 in Japan, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Embodiments of the present invention relate generally to a charged particle beam writing apparatus and a charged particle beam writing method, and more specifically, relate to, for example, a writing apparatus and method that performs transmission processing of writing data in real time in accordance with advance of writing processing.

2. Description of Related Art

The lithography technique that advances miniaturization of semiconductor devices is extremely important as a unique process whereby patterns are formed in semiconductor manufacturing. In recent years, with high integration of LSI, the line width (critical dimension) required for semiconductor device circuits is decreasing year by year. For forming a desired circuit pattern on such semiconductor devices, a master or "original" pattern (also called a mask or a reticle) of high accuracy is needed. Thus, the electron beam (EB) writing technique, which intrinsically has excellent resolution, is used for producing such a high-precision master pattern.

FIG. **9** is a conceptual diagram explaining operations of a variable shaped electron beam writing or "drawing" apparatus. The variable shaped electron beam (EB) writing apparatus operates as described below. A first aperture plate **410** has a quadrangular aperture **411** for shaping an electron beam **330**. A second aperture plate **420** has a variable shape aperture **421** for shaping the electron beam **330** having passed through the aperture **411** of the first aperture plate **410** into a desired quadrangular shape. The electron beam **330** emitted from a charged particle source **430** and having passed through the aperture **411** is deflected by a deflector to pass through a part of the variable shape aperture **421** of the second aperture plate **420**, and thereby to irradiate a target object or "sample" **340** placed on a stage which continuously moves in one predetermined direction (e.g., the x direction) during writing. In other words, a quadrangular shape that can pass through both the aperture **411** of the first aperture plate **410** and the variable shape aperture **421** of the second aperture plate **420** is used for pattern writing in a writing region of the target object **340** on the stage continuously moving in the x direction. This method of forming a given shape by letting beams pass through both the aperture **411** of the first aperture plate **410** and the variable shape aperture **421** of the second aperture plate **420** is referred to as a variable shaped beam (VSB) system.

In an electron beam writing apparatus, it is conventionally performed that writing data input from outside the apparatus is divided per predetermined calculation region so as to be allocated to a plurality of computers, and data conversion processing is performed in parallel in the plurality of computers in order to reduce a processing time for data conversion (refer to, e.g., Japanese Application Laid-open (JP-A) No. 2008-218767). Then, data for which data conversion processing has been performed in parallel is once input into a transmission processing device, and transmitted, in order of writing, to a deflection control circuit. Based on such data, the amount of beam deflection is determined so as to irradiate a target object with a deflected beam.

In a writing apparatus, it is requested to perform data transmission to the deflection control circuit without any delay, and thus to advance writing processing smoothly. However, if data transmission from a transmission processing device to a deflection control circuit is delayed and data for a writing region concerned is disconnected during the writing, the writing processing is once stopped. In an electron beam writing apparatus, when writing is performed while the stage is moving, if transmission of data for writing is delayed and the writing processing is once stopped, the stage position needs to be returned to a position where writing was performed accurately, and then, after the data for writing reaches, writing is started again. Therefore, there is a problem if the operation is once stopped, time needs to be spent in restoring the state from the stopping, which makes the writing time long.

BRIEF SUMMARY OF THE INVENTION

According to one aspect of the present invention, a charged particle beam writing apparatus includes a plurality of conversion processing units configured to perform data conversion processing in parallel for writing data of each processing region obtained by virtually dividing a writing region of a target object into a plurality of processing regions; a transmission unit configured to input apart of processing data of one of the plurality of processing regions for which the data conversion processing has been performed, one part at a time, totally as n divided processing data, and sequentially transmit the n divided processing data in a manner such that an (n−1) th divided processing data is transmitted while an n-th divided processing data is being input; a deflection control circuit configured to control a deflection amount for deflecting a charged particle beam, based on one of the n divided processing data transmitted sequentially; and a writing unit configured to write a pattern on a target object by deflecting the charged particle beam based on the deflection amount.

According to another aspect of the present invention, a charged particle beam writing method includes performing data conversion processing in parallel for writing data of each processing region obtained by virtually dividing a writing region of a target object into a plurality of processing regions; inputting a part of processing data of one of the plurality of processing regions for which the data conversion processing has been performed, one part at a time, totally as n divided processing data, and sequentially transmitting the n divided processing data to a deflection control circuit in a manner such that an (n−1) th divided processing data is transmitted while an n-th divided processing data is being input; calculating, by the deflection control circuit, a deflection amount for deflecting a charged particle beam, based on one of the n divided processing data transmitted sequentially; and writing a pattern on a target object by deflecting the charged particle beam based on the deflection amount.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram showing a configuration of a writing apparatus according to the first embodiment;

FIG. **2** shows a conceptual diagram explaining each region according to the first embodiment;

FIG. **3** is a time chart explaining a structure of data transmission according to the first embodiment;

FIG. **4** is a flowchart describing a structure of data transmission according to the first embodiment;

FIG. **5** shows an example of a transmission order list according to the first embodiment;

FIG. **6** shows main steps of an operational flow of a management unit according to the first embodiment;

FIG. **7** shows main steps of an operational flow of an input unit according to the first embodiment;

FIG. **8** shows main steps of an operational flow of a transmission unit according to the first embodiment; and

FIG. **9** is a conceptual diagram explaining operations of a variable shaped electron beam writing apparatus.

DETAILED DESCRIPTION OF THE INVENTION

In the following embodiments, there will be described a configuration in which an electron beam is used as an example of a charged particle beam. The charged particle beam is not limited to the electron beam, and other charged particle beam such as an ion beam may also be used. Moreover, a variable shaped electron beam writing apparatus will be described as an example of a charged particle beam apparatus.

In the embodiments described below, a writing apparatus and method that can perform data transmission to a deflection control circuit without any delay and perform writing processing smoothly will be explained.

First Embodiment

FIG. **1** is a schematic diagram showing a configuration of a writing apparatus according to the first embodiment. As shown in FIG. **1**, a writing (or "drawing") apparatus **100** includes a writing unit **150** and a control unit **160**. The writing apparatus **100** is an example of a charged particle beam writing apparatus. Particularly, it is an example of a variable shaped electron beam writing apparatus. The writing unit **150** includes an electron optical column **102** and a writing chamber **103**. In the electron optical column **102**, there are arranged an electron gun assembly **201**, an illumination lens **202**, a first aperture plate **203**, a projection lens **204**, a deflector **205**, a second aperture plate **206**, an objective lens **207**, a main deflector **208** and a sub deflector **209**. In the writing chamber **103**, there is arranged an XY stage **105**. On the XY stage **105**, a target object or "sample" **101** such as a mask serving as a writing target is placed when writing is performed. The target object **101** is, for example, an exposure mask used for manufacturing semiconductor devices. The target object **101** may be, for example, a mask blank on which resist is applied and a pattern has not yet been formed.

The control unit **160** includes a plurality of control computer units **110***a*-n (data conversion units), data transmission computer unit **120**, a deflection control circuit **130** (deflection calculation unit), a control circuit **132**, and a storage device **140** such as a magnetic disk drive. The plurality of control computer units **110***a*-n, the data transmission computer unit **120**, the deflection control circuit **130**, the control circuit **132**, and the storage device **140** are mutually connected through a bus (not shown).

In each of a plurality of control computer units **110***a*-n, there are arranged a plurality of CPUs and a plurality of memories.

In the data transmission computer unit **120** (an example of a transmission unit), there are arranged an input unit **34**, a buffer memory **30**, a transmission unit **32**, a transmission device **38**, and a management unit **36**. Functions, such as the input unit **34**, the transmission unit **32**, and the management unit **36** may be configured by hardware such as an electric circuit or by software such as a program causing a computer to implement these functions. Alternatively, the functions may be configured by a combination of hardware and software. Data which is input and output to/from the input unit **34**, the transmission unit **32**, and the management unit **36**, and data being operated are stored in a memory (not shown) each time.

In the deflection control circuit **130**, there are arranged a buffer memory **40** and a deflection amount calculation unit **42**. Functions, such as the deflection amount calculation unit **42** may be configured by hardware such as an electric circuit or by software such as a program causing a computer to implement these functions. Alternatively, the function may be configured by a combination of hardware and software. Data which is input and output to/from the deflection amount calculation unit **42**, and data being operated are stored in a memory (not shown) each time.

FIG. **1** shows a configuration necessary for explaining the first embodiment. Other configuration elements generally necessary for the writing apparatus **100** may also be included. For example, a multiple stage deflector of two stages of the main deflector **208** and the sub deflector **209** is herein used for position deflection. However, a single stage deflector or a multiple stage deflector of three or more stages may also be used for position deflection.

Writing data in which positions, sizes, and the like of a plurality of figure patterns are defined is input into the storage device **140** from the outside to be stored therein.

FIG. **2** shows a conceptual diagram explaining each region according to the first embodiment. In FIG. **2**, a writing region **10** of the target object **101** is virtually divided into a plurality of stripe regions **20** each having a strip shape and a width deflectable in the x or y direction by the main deflector **208**. Moreover, each stripe region **20** is divided into a plurality of data processing blocks (DPB) **31** (an example of a processing region).

FIG. **3** is a time chart explaining a structure of data transmission according to the first embodiment. Apart (a) of FIG. **3**, as a comparative example of the first embodiment, shows the case where data is transmitted by the DPB **31**. In the comparative example as shown in the part (a) of FIG. **3**, data conversion processing of one DPB **31** is performed in the control computer unit **110** serving as a data conversion unit. Specifically, the CPU in the control computer unit **110** reads writing data corresponding to each DPB region **31** from the storage device **140**, and performs data conversion processing of a plurality of steps to generate apparatus-specific shot data. Then, the shot data of the DPB region **31** concerned for which data conversion processing has been performed is collectively output by the DPB region **31** to the data transmission computer unit **120**.

Then, in the data transmission computer unit **120**, the input shot data of the DPB region **31** concerned is collectively output by the DPB region **31** to the deflection control circuit **130**. In the deflection control circuit **130**, writing processing does not start until transmission of shot data of each DPB region **31** has been completed. Thus, in the comparative example, writing processing cannot be started until the entire shot data of one DPB region **31** reaches the deflection control circuit **130**. Therefore, if transmission processing is delayed and thus transmission of the entire

shot data of the present DPB region **31** has not been completed before writing processing of the DPB region being one region before the present DPB region **31** is completed, the writing processing becomes once stopped. In the writing apparatus **100**, when, for example, writing is performed while the XY stage **105** is continuously moving, if shot data of a next DPB region **31** is delayed, writing processing is once stopped.

However, since it is difficult to instantly stop the XY stage **105**, the position of the stage deviates from an expected position. Therefore, when writing processing is once stopped, the stage position needs to be returned to a position where writing was performed accurately, and then, after shot data for a next DPB region **31** reaches the deflection control circuit **130**, writing is started again. Therefore, if the operation is once stopped, there is a problem that time needs to be spent in restoring the state from the stopping, which makes the writing time long.

Then, according to the first embodiment, as shown in a part (b) of FIG. **3**, data transmission is not performed by the DPB region **31**, but shot data of the DPB region **31** for which data conversion processing has been performed is divided into a plurality of divided processing data. For example, it is divided into predetermined data amounts. In the case of the part (b) of FIG. **3**, shot data of one DPB region **31** is divided into five divided processing data of 1 to 5 in order of writing. The number of divisions is not limited to five. It may be less or more than five as long as it is divided into a plurality of divided processing data.

In the data transmission computer unit **120**, a part of shot data of the DPB region **31** for which data conversion processing has been performed is sequentially input, one part at a time, totally as n divided processing data. In the case of the part (b) of FIG. **3**, five divided processing data of 1 to 5 is input in order of writing. In the case of the part (b) of FIG. **3**, first, the data transmission computer unit **120** inputs the first divided processing data (time zone t_1). Next, while inputting the second divided processing data, the data transmission computer unit **120** transmits the first divided processing data to the deflection control circuit **130** (time zone t_2). Next, while inputting the third divided processing data, the data transmission computer unit **120** transmits the second divided processing data to the deflection control circuit **130** (time zone t_3). Next, while inputting the fourth divided processing data, the data transmission computer unit **120** transmits the third divided processing data to the deflection control circuit **130** (time zone t_4). Thus, while inputting the n-th divided processing data, the data transmission computer unit **120** transmits the (n−1) th divided processing data to the deflection control circuit **130** (time zone t_n). In other words, input processing and transmission processing of n divided processing data are performed by pipeline processing in order of writing. The time zones **1** to **6** show time zones arranged in order.

As described above, n divided processing data is transmitted in order. Thereby, after the time zone t_2 has elapsed, transmission of the first divided processing data to the deflection control circuit **130** is completed. Then, after the subsequent time zone t_3 has elapsed, transmission of the second divided processing data to the deflection control circuit **130** is completed. After the time zone t_{n+1} being after the time zone t_n has elapsed, transmission of the n-th divided processing data to the deflection control circuit **130** is completed. However, if the transmission time of divided processing data from the data transmission computer unit **120** to the deflection control circuit **130**, that is the transmission time of the data transmission computer unit **120**, is longer than the transmission time of divided processing data from the control computer unit **110** to the data transmission computer unit **120**, that is the input time of the data transmission computer unit **120**, it is sufficient for the data transmission computer unit **120** to perform transmission processing after the previous transmission processing has been completed.

In the comparative example, as shown in the part (a) of FIG. **3**, it is difficult to start writing processing until the time zone t_6 shown in the part (b) of FIG. **3** has elapsed (time T_2). However, according to the first embodiment, writing processing can be started after the time zone t_2, that is the arrival time of the first divided processing data at the deflection control circuit **130**, has elapsed (time T_1). Therefore, writing processing can be started earlier by the difference ΔT between the time T_1 and the time T_2. Accordingly, the stop of the writing processing due to waiting for data transmission as in the comparative example can be eliminated or reduced. The operation contents are concretely described below.

FIG. **4** is a flowchart describing the structure of data transmission according to the first embodiment.

In a data conversion step, a plurality of control computer units **110***a*-n (an example of a data conversion unit or a conversion processing unit) perform data conversion processing of writing data in parallel for each DPB region **31** obtained by virtually dividing the writing region **10** of the target object **101** into a plurality of DPB regions **31** (processing regions). The CPU in each of a plurality of control computer units **110***a*-n reads writing data corresponding to each DPB region **31** from the storage device **140**, performs data conversion processing of a plurality of steps, and generates apparatus-specific shot data. Thus, by performing data processing in parallel, the data processing can be executed at a high speed. For actually writing a figure pattern by the writing apparatus **100**, it is necessary to divide each figure pattern defined in writing data into the size that can be irradiated by one beam shot. Then, the CPU in each of a plurality of data conversion units **110***a*-n generates a shot figure by dividing a figure pattern indicated by writing data into the size that can be irradiated by one beam shot. Shot data is generated for each shot figure. The shot data defines figure data, such as a figure type, figure size, irradiation position and dose, for example. Further, according to the first embodiment, the header of each shot data defines writing order information indicating a writing order.

Writing order information is in the header of each shot data. For example, DPB information is defined, and then, a writing order is represented by the DPB information. For example, when DPB information is defined for each stripe region **20**, stripe region information is also defined. It is preferable to use, for example, an ID (identifier or address) of the DPB region, as the DPB information. Writing processing is performed for each DPB in order of increasing position indicated by the DPB region ID from the smallest, for example. Alternatively, writing processing is performed for each DPB in order of increasing distance of the position indicated by the ID from the closest to the writing starting position of each stripe region, for example. Alternatively, it is also preferable to define a number for each of a plurality of DPBs such that each number indicates the order of writing processing of a DPB concerned.

Then, figure data, such as a figure type, figure size, irradiation position, and dose, is defined after the header. Shot data calculated by the CPU in each of a plurality of control computer units **110***a*-n is stored in a memory corresponding to each CPU.

In a data generation completion notification transmission step, when data conversion processing in the DPB region **31** concerned has been completed in each of the control computer units **110***a*-n, a data generation completion notification is transmitted to the control circuit **132** from each of the control computer units **110***a*-n.

In a transmission order list generation step, receiving the input of the data generation completion notification from each of the control computer units **110***a*-n, a transmission order list is generated in the control circuit **132** (generation unit).

FIG. **5** shows an example of the transmission order list according to the first embodiment. In the transmission order list, there are defined DPB region IDs and identifiers (IDs) of the control computer units **110***a*-n which performed data conversion processing of the DPB regions **31** indicated by the DPB region IDs. The DPB region ID defines a serial ID in the system for the entire writing region **10** of the target object **101**, a number of the stripe region **20** to which the DPB region **31** concerned belongs, and a serial ID of the DPB region **31** concerned in the stripe region **20** concerned. The example of FIG. **5** shows a list in which shot data of the DPB region **31**, where "**31**" is a serial ID in the entire writing region **10**, "**1**" is a stripe region ID to which the DPB region having a serial number **31** belongs, and "**2**" is a serial ID in the stripe region **20** whose ID is "**1**", is defined at the head of the list. Moreover, it shows that the ID of the control computer unit **110** which performed data conversion processing in the DPB region **31** concerned is "A". Similarly, with respect to the DPB region in the second line of the list, "**32**" is a serial ID in the entire writing region **10**, "**1**" is a stripe region ID to which the DPB region having a serial number **32** belongs, "**2**" is a serial ID in the stripe region **20** whose ID is "**1**", and the ID of the control computer unit **110** which performed data conversion processing is "B". Similarly, with respect to the DPB region in the third line of the list, "**33**" is a serial ID in the entire writing region **10**, "**1**" is a stripe region ID to which the DPB region having a serial number **33** belongs, "**2**" is a serial ID in the stripe region **20** whose ID is "**1**", and the ID of the control computer unit **110** which performed data conversion processing is "C". That is, three DPB regions **31** having serial IDs from "**31**" to "**33**" in the entire writing region **10** are in the list of FIG. **5**.

In the transmission order list, the DPB regions are arranged in order of writing. For example, with respect to a DPB region having a serial ID after "**31**" in the entire writing region **10**, even when the data generation completion notification of a DPB region having a serial ID after "**32**" has been transmitted to the control circuit **132**, the DPB region having the serial ID after "**32**" is not written in the transmission order list until the data generation completion notification of the DPB region having the serial ID "**31**" reaches the control circuit **132**. On the contrary, when the data generation completion notification of a DPB region having a serial ID after "**32**" has not been transmitted to to the control circuit **132** and only the data generation completion notification of the DPB region having the serial number "**31**" has reached the control circuit **132**, a transmission order list is generated such that only one DPB region having the serial ID "**31**" is defined in the list. The generated transmission order list is transmitted from the control circuit **132** to the management unit **36** in the data transmission computer unit **120**.

In an input (import) request step, the management unit **36** requests the input unit **34** to input the data. Specifically, it operates as described below.

FIG. **6** shows main steps of an operational flow of the management unit according to the first embodiment.

In an addition step (S**106**) to an import request list, when inputting a transmission order list, an addition processing function unit (not shown) of the management unit **36** adds DPB information shown in the transmission order list to the import request list. The contents of the import request list may be the same as those of the transmission order list shown in FIG. **5**. Similarly to the transmission order list, listing is performed in order of writing in the import request list.

In an addition step (S**108**) to a transmission request list, when inputting a transmission order list, an addition processing function unit (not shown) of the management unit **36** adds DPB information shown in the input transmission order list to another transmission order list (transmission request list) uniquely owned by the transmission unit **32**. The contents of the transmission request list may be the same as those of the transmission order list shown in FIG. **5**. Specifically, for example, when the first transmission order list is transmitted from the control circuit **132** to the management unit **36**, the contents of the another transmission order list (transmission request list) uniquely owned by the transmission unit **32** are the same as those of the first transmission order list transmitted from the control circuit **132**. If, for example, the second transmission order list is transmitted from the control circuit **132** to the management unit **36** before transmission of the DPB defined in the first transmission order list has been completed, the contents of the second transmission order list are connected to the rear of the another transmission order list (transmission request list), in the current state, uniquely owned by the transmission unit **32**. Thereby, the contents of the transmission order list sequentially transmitted from the control circuit **132** are reflected to another transmission order list uniquely owned by the transmission unit **32**.

That DPB information is added to an import request list indicates that the input unit **34** is requested to input data. Then, the input unit **34** operates as described below.

FIG. **7** shows main steps of an operational flow of the input unit according to the first embodiment.

First, in a determination step (S**202**), a determination function unit (not shown) of the input unit **34** determines whether the import request list is empty (no DPB information). When the import request list is empty, it returns to the determination step (S**202**).

In a determination step (S**204**), when the import request list is not empty, a determination function unit (not shown) of the input unit **34** determines whether the DPB region whose data is to be imported is defined at the head of the transmission order list. If the DPB region is not defined at the head, it goes to flow (A), and if it is defined at the head, it goes to flow (B). The flows (A) and (B) correspond to the flows surrounded by the dotted lines of FIG. **4**. That is, in the determination step (S**204**), one of the flows (A) and (B) is to be selected. The flow (A) shows a flow of collectively performing transmission processing of the entire shot data of the DPB region. The flow (B) shows a flow of dividing shot data of the DPB region into a plurality of divided processing data, and sequentially transmitting a plurality of divided processing data. First, the flow (A) is described below.

In a determination step (S**206**), a determination function unit (not shown) of the input unit **34** determines whether the buffer memory **30** has a space for storing the entire shot data of the DPB region **31** concerned. When there is no space, it returns to the determination step (S**206**).

In a deletion step (S208) from a list, a deletion function unit (not shown) of the input unit **34** deletes information on the target DPB region from the import request list.

In an import step (S210), first, a transmission function unit (not shown) of the input unit **34** sends a request to the control computer unit **110** which performed data conversion of the target DPB region to transmit shot data of the target DPB region. The control computer unit **110** to be an object can be identified by ID of the control computer unit **110** defined in the import request list (or transmission order list). The control computer unit **110** concerned transmits shot data of the target DPB region to the input unit **34**. Thereby, an import function unit (not shown) of the input unit **34** inputs (imports) shot data of the target DPB region from the control computer unit **110** concerned. The input shot data of the target DPB region is temporarily stored (recorded) in the buffer memory **30**.

In a registration step (S212), a registration function unit (not shown) of the input unit **34** registers the target DPB region whose shot data has been input into the input unit **34**, as an imported DPB.

In a report step (S214), a transmission function unit (not shown) of the input unit **34** reports the management unit **36** that importing shot data of the target DPB region has been completed. Then, it returns to the determination step (S202). Each step after the determination step (S202) is repeated until the import request list becomes empty.

Next, the flow (B) is described below. When determined in the determination step (S204) that the DPB region whose data is to be imported is defined at the head of the transmission order list, there is a high possibility at that time that the transmission unit **32** has not transmitted the shot data of the DPB region. Therefore, shot data transmission of the DPB region is likely to be delayed. Then, according to the first embodiment, when the DPB region for which input processing is to be started is located at the head of the transmission order list, the input unit **34** inputs processing data of the DPB region concerned in order, as n divided processing data, and transmits them in order. In the flow (B), the input unit **34** instead of the transmission unit **32** carries out processing of transmission to the deflection control circuit. In such a case, the input unit **34** serves as an example of the transmission unit.

In a determination step (S220), a determination function unit (not shown) of the input unit **34** determines whether the transmission device **38** is in use or not at the time. If the transmission device **38** is in use and unavailable, it goes to the determination step (S206). If the transmission device **38** is in use, since it means that the shot data transmission of the DPB region is not delayed, there is no necessity of daring to carry out division into divided processing data. Therefore, what is necessary is just to return to the usual flow (A).

In a reservation step (S222), when the transmission device **38** is not in use, a reservation function unit (not shown) of the input unit **34** provides a transmission device reservation in order to use the transmission device **38**.

In a determination step (S224), a determination function unit (not shown) of the input unit **34** determines whether the buffer memory **30** has a space for storing the divided processing data of the DPB region **31** concerned. If there is no sufficient space, it returns to the determination step (S224). Since the data amount of the divided processing data is sufficiently smaller than that of the entire shot data of one DPB region **31**, the determination threshold value used here may be smaller than the determination threshold value used in the determination step (S206). For example, it is sufficient that a space capable of storing at least two or more divided processing data remains.

In a deletion step (S226) from a list, a deletion function unit (not shown) of the input unit **34** deletes information on the target DPB region from the import request list.

In a divided data import step (S228), first, a transmission function unit (not shown) of the input unit **34** sends a request to the control computer unit **110** which performed data conversion of the target DPB region to transmit the n-th divided processing data of shot data of the target DPB region. Here, since it is the beginning, a request to transmit the first divided processing data is sent. The control computer unit **110** to be an object can be identified by ID of the control computer unit **110** defined in the import request list (or transmission order list). The control computer unit **110** concerned transmits the n-th divided processing data of shot data of the target DPB region to the input unit **34**. Thereby, an import function unit (not shown) of the input unit **34** inputs (imports) the n-th divided processing data of shot data of the target DPB region from the control computer unit **110** concerned. The input n-th divided processing data of shot data of the target DPB region is temporarily stored (recorded) in the buffer memory **30**.

Here, the writing unit **150** incudes the main deflector **208** and the auxiliary deflector **209** that deflect an electron beam **200** to the target object **101**. A plurality of mesh subfields (SF) deflectable by the main deflector **208** and the auxiliary deflector **209** are set in the DPB region **31**. Moreover, the number of shots in a subfield is defined in shot data (processing data), for each subfield. For example, a subfield header is defined for each subfield, and the subfield header defines an ID indicating the address of the subfield concerned and the number of shots of the electron beam to be shot in the the subfield concerned. However, when dividing of shot data into a plurality of divided processing data is performed by the desired size, it may be divided in the middle of the subfield. If dividing is defined by the data size, the possibility of being divided in the middle of the subfield may be higher than that of not being divided in the middle of it. Therefore, if divided in the middle of a subfield, one of divided processing data includes the subfield header of the subfield which has been divided, but the number of shots assigned by the division differs from the number of shots originally defined in the subfield header. The other of divided processing data includes no subfield header of the subfield which has been divided, and the number of shots assigned by the division is not defined in the data. Then, for this insufficient data structure, correction is performed as described below.

In a rewrite step (S230), with respect to one of divided processing data generated due to division in the middle of the subfield, a rewrite function unit (not shown) of the input unit **34** rewrites the number of shots which is originally defined for the subfield that has been divided and is defined in the divided processing data concerned to the number of shots assigned to the divided processing data concerned by the division. Moreover, with respect to the other of divided processing data which was also generated due to the division in the middle of the subfield and is to be input next, the rewrite function unit (not shown) of the input unit **34** generates a subfield header of the divided subfield after being input, and writes (defines) the number of shots assigned to the divided processing data concerned by the division in the generated subfield header. By this processing, information omitted or changed by the division can be corrected in each divided processing data.

In a determination step (S232), a determination function unit (not shown) of the input unit **34** determines whether all the divided processing data of the DPB region concerned has been imported. If there still remains divided processing data that has not been imported in all the divided processing data of the DPB region concerned, it returns to the divided data import step (S228). Then, importing of next divided processing data is performed in the divided data import step (S228). Each step from the divided data import step (S228) to the determination step (S232) is repeated until all the divided processing data has been imported.

In a registration step (S234), when all the divided processing data of the DPB region concerned has been imported, a registration function unit (not shown) of the input unit **34** registers an input target DPB region as an imported DPB, and then it goes to a determination step (S238).

In a divided data transmission step (S236), a transmission function unit (not shown) of the input unit **34** transmits divided processing data that has been input earlier to the deflection control circuit **130**. In this case, for example, it is preferable to start transmission to the deflection control circuit **130** immediately after the first divided processing data has been input and the rewrite step (S230) has been completed. The transmission processing is actually performed by the transmission device **38**, based on the control from the transmission function unit (not shown) of the input unit **34**.

In a determination step (S238), a determination function unit (not shown) of the input unit **34** determines whether all the divided processing data of the DPB region concerned has been transmitted. If there still remains divided processing data that has not been transmitted in all the divided processing data of the DPB region concerned, it returns to the divided data transmission step (S236). Then, transmission of next divided processing data is executed in the divided data transmission step (S236). Each step from the divided data transmission step (S236) to the determination step (S238) is repeated until all the divided processing data has been transmitted.

According to the first embodiment, as described referring to FIG. **3**, the input unit **34** (an example of the transmission unit) inputs a part of shot data of the DPB region for which data conversion processing has been performed, one part at a time, totally as n divided processing data, and sequentially transmits the n divided processing data in a manner such that the (n−1)th divided processing data is transmitted while the n-th divided processing data is being input.

In a list deletion step (S240), a deletion function unit (not shown) of the input unit **34** deletes information on a target DPB region from a transmission order list uniquely owned by the transmission unit **32**.

In a device release step (S242), a release function unit (not shown) of the input unit **34** releases a reserved transmission device **38**.

In a report step (S244), a transmission function unit (not shown) of the input unit **34** reports to the control circuit **132** and the management unit **36** that transmission of shot data of a target DPB region has been completed. Then, it returns to the determination step (S202). Each step after the determination step (S202) is repeated until the import request list becomes empty.

Next, operations of the transmission unit **32** will be described. When the transmission order list uniquely owned by the transmission unit **32** is not empty, data transmission is requested to the transmission unit **32**. The transmission unit **32** operates as described below.

FIG. **8** shows main steps of an operational flow of the transmission unit according to the first embodiment. The transmission unit **32** operates when the flow (A) of FIG. **4** is performed. First, in a determination step (S302), a determination function unit (not shown) of the transmission unit **32** determines whether the transmission request list is empty (no DPB information). When the transmission request list is empty, it returns to the determination step (S302).

In a determination step (S304), when a transmission order list uniquely owned by the transmission unit **32** is not empty, a determination function unit (not shown) of the transmission unit **32** determines whether shot data of the DPB region which is defined at the head of the transmission order list has already been imported into the buffer memory **30**. When the shot data of the DPB region defined at the head has not been imported, it returns to the determination step (S302).

In a determination step (S306), when the shot data of the DPB region defined at the head has already been imported, a determination function unit (not shown) of the transmission unit **32** determines whether the transmission device **38** is not in use at the time. When the transmission device **38** is in use and unavailable, it returns to the determination step (S302).

In a reservation step (S308), when the transmission device **38** is not in use, a reservation function unit (not shown) of the transmission unit **32** provides a transmission device reservation in order to use the transmission device **38**.

In a list deletion step (S310), a deletion function unit (not shown) of the transmission unit **32** deletes information on the target DPB region from the transmission order list uniquely owned by the transmission unit **32**.

In a data transmission step (S312), a transmission function unit (not shown) of the transmission unit **32** transmits the shot data of the DPB region, which is defined at the head of the transmission order list uniquely owned by the transmission unit **32** and has already been imported, to the deflection control circuit **130**. Based on the control from the transmission function unit (not shown) of the transmission unit **32**, transmission processing is actually performed by the transmission device **38**.

In a device release step (S314), a release function unit (not shown) of the transmission unit **32** releases a reserved transmission device **38**.

In a report step (S316), a transmission function unit (not shown) of the transmission unit **32** reports to the control circuit **132** and the management unit **36** that transmission of shot data of the target DPB region has already been completed. Then, it returns to the determination step (S302). Each step after the determination step (S302) is repeated until the transmission order list uniquely owned by the transmission unit **32** becomes empty.

As described above, shot data of each DPB region is temporarily stored in the buffer memory **40** in the deflection control circuit **130** in a manner such that the entire shot data of each DPB region is collectively stored, or shot data of each DPB region is divided into a plurality of divided processing data to be sequentially stored. Accordingly, shot data or divided processing data of the DPB region **31** can be stored without any delay, in the order of writing processing, in the buffer memory **40** of the deflection control circuit **130**.

The deflection control circuit **130** controls a deflection amount for deflecting an electron beam, based on shot data or divided processing data having been transmitted sequentially.

In a deflection amount calculation step, the deflection amount calculation unit **42** reads processing data (shot data or divided processing data) from the buffer memory **40** in

order of writing, and calculates deflection amounts to be deflected by the deflector **205**, the main deflector **208**, and the sub deflector **209** respectively. Then, a digital signal indicating a deflection amount is output to a digital-analog conversion (DAC) amplifier unit (not shown) for each deflector. Then, in each DAC amplifier unit, the digital signal output from the deflection control circuit **130** is converted to an analog signal and amplified to be applied as a deflection voltage to the deflector **205**, the main deflector **208**, or the sub deflector **209**. Thus, the deflection control circuit **130** controls the deflection amount for deflecting the electron beam **200**, based on processing data for each DPB region **31** transmitted from the data transmission computer unit **120**.

In a writing step, the writing unit **150** controlled by the control circuit **132** writes a pattern on the target object **101** by deflecting the electron beam **200** based on the deflection amount. Specifically, it operates as described below.

The electron beam **200** emitted from the electron gun assembly **201** (emission unit) irradiates the whole of the first aperture plate **203** having a quadrangular opening by the illumination lens **202**. At this point, the electron beam **200** is shaped to be a quadrangle. Then, after having passed through the first aperture plate **203**, the electron beam **200** of a first aperture image is projected onto the second aperture plate **206** by the projection lens **204**. The first aperture image on the second aperture plate **206** is deflected and controlled by the deflector **205** so as to change the shape and size of the beam to be variably shaped. After having passed through the second aperture plate **206**, the electron beam **200** of a second aperture image is focused by the objective lens **207**, and deflected by the main deflector **208** and the sub deflector **209** to reach a desired position on the target object **101** placed on the XY stage **105** which moves continuously. FIG. **1** shows the case of using multiple stage deflection of the main and sub deflection for position deflection. In such a case, the main deflector **208** deflects the electron beam **200** of a shot concerned to a reference position in a subfield (SF), which is obtained by virtually dividing the writing region of the target object by the main deflector **208**, while following the movement of the stage, and the sub deflector **209** deflects the shot beam concerned to each irradiation position in the SF.

According to the first embodiment, as described above, data transmission to the deflection control circuit **130** can be performed without any delay. Therefore, writing processing can be smoothly carried out.

The embodiment has been explained referring to concrete examples described above. However, the present invention is not limited to these specific examples.

While the apparatus configuration, control method, and the like not directly necessary for explaining the present invention are not described, some or all of them can be selectively used case-by-case basis. For example, although description of the configuration of the control unit for controlling the writing apparatus **100** is omitted, it should be understood that some or all of the configuration of the control unit can be selected and used appropriately when necessary.

In addition, any other charged particle beam writing apparatus and charged particle beam writing method that include elements of the present invention and that can be appropriately modified by those skilled in the art are included within the scope of the present invention.

Additional advantages and modification will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A charged particle beam writing apparatus, comprising:

a plurality of conversion processing units configured to perform data conversion processing in parallel for writing data of each processing region obtained by virtually dividing a writing region of a target object into a plurality of processing regions;

a transmission unit configured to input a part of processing data of one of the plurality of processing regions for which the data conversion processing has been performed, one part at a time, totally as n divided processing data, and sequentially transmit the n divided processing data in a manner such that an (n−1)th divided processing data is transmitted while an n-th divided processing data is being input;

a deflection control circuit configured to control a deflection amount for deflecting a charged particle beam, based on one of the n divided processing data transmitted sequentially; and

a writing unit configured to write a pattern on a target object by deflecting the charged particle beam based on the deflection amount,

wherein processing data of one processing region for which the data conversion processing is performed by one of the plurality of conversion processing units is divided into the n divided processing data.

2. The apparatus according to claim **1**, wherein input processing and transmission processing for the n divided processing data are performed by pipeline processing in order of writing.

3. The apparatus according to claim **1**, wherein

the writing unit includes a deflector for deflecting the charged particle beam to the target object,

a plurality of subfields each to be deflected by the deflector are set in each of the plurality of processing regions,

a number of shots for each of the plurality of subfields is defined in the processing data, for each of the plurality of subfields, and

the transmission unit, with respect to divided processing data generated due to division in a middle of one of the plurality of subfields in one of the plurality of processing regions, rewrites the number of shots which is originally defined for the one of the plurality of subfields that has been divided and is defined in the divided processing data to a number of shots assigned to the divided processing data by the division.

4. The apparatus according to claim **1**, wherein

the transmission unit inputs a transmission order list in which the plurality of processing regions are arranged and defined in order of data transmission, and when one of the plurality of processing regions which is to be input is located at a head of the transmission order list, inputs processing data of the one of the plurality of processing regions sequentially totally as the n divided processing data, and transmits the n divided processing data sequentially.

5. The apparatus according to claim **4**, further comprising:

a generation unit configured to generate the transmission order list, wherein,

the transmission order list defines an identifier of one of the plurality of processing regions, and an identifier of one of the plurality of conversion processing units

which performed data conversion processing of the one of the plurality of processing regions.

6. The apparatus according to claim **5**, wherein

the one of the plurality of conversion processing units which completed the data conversion processing of the one of the plurality of processing regions transmits a data generation completion notification to the generation unit,

the writing region of the target object is virtually divided into a plurality of stripe regions,

serial identifiers are defined for processing regions, belonging to each of the plurality of stripe regions, in the plurality of processing regions, and

even when a data generation completion notification of one of the plurality of processing regions whose serial identifier is k has been transmitted to the generation unit, the one of the plurality of processing regions whose serial identifier is k is not defined in the transmission order list until a data generation completion notification of one of the plurality of processing regions whose serial identifier is (k−1) reaches the generation unit.

7. A charged particle beam writing method, comprising:

performing data conversion processing in parallel for writing data of each processing region obtained by virtually dividing a writing region of a target object into a plurality of processing regions;

inputting a part of processing data of one of the plurality of processing regions for which the data conversion processing has been performed, one part at a time, totally as n divided processing data, and sequentially transmitting the n divided processing data to a deflection control circuit in a manner such that an (n−1)th divided processing data is transmitted while an n-th divided processing data is being input;

calculating, by the deflection control circuit, a deflection amount for deflecting a charged particle beam, based on one of the n divided processing data transmitted sequentially; and

writing a pattern on a target object by deflecting the charged particle beam based on the deflection amount,

wherein processing data of one processing region for which the data conversion processing is performed by one of a plurality of conversion processing units is divided into the n divided processing data.

8. The method according to claim **7**, further comprising:

inputting a transmission order list in which the plurality of processing regions are arranged and defined in order of data transmission, wherein

inputting sequentially, when one of the plurality of processing regions which is to be input is located at a head of the transmission order list, processing data of the one of the plurality of processing regions, totally as the n divided processing data, and transmitting the n divided processing data sequentially.

9. The method according to claim **8**, further comprising:

inputting collectively, when one of the plurality of processing regions which is to be input is not located at the head of the transmission order list, whole processing data of the one of the plurality of processing regions and transmitting the whole processing data.

10. The method according to claim **7**, further comprising:

transmitting a data generation completion notification with respect to the one of the plurality of processing regions for which the data conversion processing has been completed in the plurality of processing regions;

generating, when inputting the data generation completion notification, a transmission order list in which the plurality of processing regions for each of which the data conversion processing has been completed are arranged and defined in order of data transmission; and

requesting, when inputting the transmission order list, to import data of the one of the plurality of processing regions for which the data conversion processing has been completed.

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